

University of Groningen

Authority structure and industrial accidents

As, Sicco van

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:
2001

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

As, S. V. (2001). *Authority structure and industrial accidents*. s.n.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Authority Structure and Industrial Accidents

Sicco van As

SOM-theme A: Primary processes within firms

Abstract

This paper deals with the influence of organizational characteristics on safety. Accidents are actually caused by individual mistakes. However the underlying causes of accidents are often organizational. The general hypothesis is that the authority structure is a main cause of accident-proneness within organizations. On one side, the most obvious model for a safe organization would be the ideal-typical bureaucracy. On the other side, potential problems are little flexibility and control is based on (lacking) knowledge. I discern hierarchy as a separate element of bureaucracy, and distinguish different aspects of authority. The analysis shows several significant correlations, and the distinction between control and management seems to be of interest for safety.

1 Introduction

Many industrial processes have potentially disastrous outcomes for workers and the environment. Most literature dealing with occupational safety emphasizes unsafe working conditions or individual characteristics. The research to be presented in this paper relates to organizational characteristics as a cause of accident-proneness in different industrial organizations. Here the concept of organization relates to human activities performed to produce goods. It implies both the functions and tasks within the production, maintenance and shipping sequences of (chemical) industry. By organization I understand a group of interrelated functions and tasks; it comprises formal organization as the product of intended organization design (designed to set collective goals and make arrangements to deploy available resources to attain those goals) and informal organization as a coalition of multiple, possibly conflicting interests characterized by rules not laid down in procedures.

It is the result of a long tradition that accidents are most times studied as the result of technical - or human errors. In this paper I would like to discuss the work organization as a cause of accidents, and organizing as a risky activity. I will first define the concept of safety as a performance measure, and as a dependent variable. Because “[b]efore anything can be studied scientifically, it must be defined. This step, which sounds so easy, has been a stumbling block for accident research ever since its early days” (Hale and Hale 1972:11, Osborn and Jackson 1988:925). Here I would like to study the influence of authority structure on safety. More precise: the way in which authority is structured to cope with future events and their uncertainties (within the production, maintenance and shipping sequences of chemical industry). Research indicates that at least some aspects of authority structure seem to be a potential leverage of accident-proneness (e.g. Sagan 1995, Perrow 1999), and “[a]rranging authority over professional workers like engineers is always problematic” (Stinchcombe and Heimer 1985:20). Different dimensions of authority structure will be measured and analyzed.

One speaks of risk because, in any particular instance, an accident may or may not occur; causative factors skew the probabilities of different outcomes (Graham and Rhomberg 1996:15). From an organizational perspective risk is about problems of decision-making in the face of uncertainty. Here probability cannot be calculated in a quantitative way but it can only be described in relative terms like ‘more’ or ‘less’ (proneness). This view of probability points to the main difference between the mathematical and sociological approach of risk: the concept of uncertainty. Uncertainty refers to the complexity of social reality on one side, and to cognitive limitations on the other.

Nowadays, in sociology, definitions and interpretations of risk follow the ‘uncertainty approach’¹. Here I adopt a broad definition from everyday English and everyday life. Risk will be defined as: ‘human activities that might cause an accident’. The words ‘human activities’ point at the role of a voluntaristic actor (or: agent) and distinguishes the concept from danger²; human action can reduce or increase the probability (and size) of the damage. This definition fits closely the way in which the concept of risk is used within accident- or safety research. It only involves ‘down-side risk’: problems or accidents, and not the opportunities. Here it equals ‘accident-proneness’³ (or: operational risk); which is conceived as the opposite of safety or reliability.

¹This also includes economics. Except for ‘financial risk’, which is closely fitted with the mathematical view of risk. “Risk control in asset management is the ability to manage the uncertainty associated with the investment process. Fundamental to [financial] risk control is risk measurement, which can be thought of as quantification of the characteristics of risk” (Fong and Vasicek 1997:51).

²In literature many different concepts are used, with a slightly different meaning. E.g. danger seems to refer to the possibility that something unpleasant or undesirable might happen without the intervention of an agent, e.g. getting struck by lightning while playing a game of football. The related concept of hazard seems to refer to the unpleasant results of technological characteristics (design, construction, material, etc.).

³This meaning of proneness is different from the one in the human error literature. The human error approach focuses on proneness as differences in personal attributes; so-called error-proneness, e.g. clumsiness (e.g. Hale and Hale 1972:15, Dwyer 1991:56-57). In this research accident-prone is considered to be an organizational instead of an individual (performance) characteristic.

Based on the observation that accidents are actually caused by mistakes (e.g.: Heinrich 1959:13 Leplat 1987:133-, Reason 1990, Adams 1995:16), I will regard mistakes (including dangerous behaviour and attitudes⁴) as an aspect of accident-proneness. Of course another aspect are (near-) accidents itself. A near-accident (or 'near miss') is an incident that in other circumstances could have resulted in an accident. An (industrial) accident is a sudden disturbance within the primary process, as a consequence of unintended human action, that results in physical harm or serious damage to equipment or environment. So, mistakes are the proximate cause of accidents and will even be regarded as an aspect of accident-proneness. However, as we will see, the underlying causes of accidents are organizational.

As can be deduced from the definition introduced before, an organization can be seen as a structured (or: 'patterned') group of functions and tasks. Structure is an analytically distinctive aspect of an organization, which refers to the distribution of authority; 'authority structure'. Weber defined authority as 'types of legitimate domination', where domination is the "probability that certain specific commands (or all commands) will be obeyed by a given group of persons" (Weber 1968:212). Here authority is the legitimate discretion conferred on people to manage and control other people. As can be derived from this description, I distinguish two separate aspects of authority: control and management. Control is the process of establishing standards, measuring performance against these standards, and correcting variations from standards and plans (e.g. Wehrich and Koontz 1993:578). Management is also a planning process, but here the standard is not preset: 'organizing'. Control will be given further consideration by a discussion of the ideal-typical bureaucracy. After, I will go deeper into management.

⁴For the use of mistakes, dangerous behaviour, and attitudes as 'alternative criteria for study' see: Hale and Hale 1972:13-4

2 Organizational approach: bureaucracy

In literature different abbreviations are used as more or less metaphorical names of extrinsic influences on accidents: e.g. BRFs (Basic Risk Factors), GFTs (General Failure Types) and 'Pathogens' (germs of a disease already present in a body before the actual disease). They all represent approaches that accept mistakes as the immediate determinant and hypothesize the BRF's, GFT's, etc. to symbolize the final deciding factors.

Different factors can be distinguished. Probably the main part of the surroundings is the organization in which the work is executed. Along with the (technical and) human error approach I can now distinguish the organizational approach, which explains accidents at the operational level from the work organization in which they take place. Analyses of accidents within nuclear industries (e.g. Harrisburg, Chernobyl) and chemical industries (e.g. Piper Alpha, Bhopal) demonstrate that even in industries generally associated with high technology, underlying causes of accidents are often organizational, rather than psychological or technical (Bea and Moore 1993:203). The organizational approach is not so much focused on the characteristics of individuals (or technical systems), but rather on the (organizational) context in which people (and technical systems) work together. The organizational characteristics that are related to mistakes and accidents in the primary process (accident-proneness) can be seen as 'organizational failures'. Here I would like to study which aspects of the authority structure are correlated with accident-proneness

In the quest for a suitable model of regulation the most obvious model is the bureaucratic structure of authority. The proper application of scientific principles to management reinforces the Weberian concept of bureaucratic administration as the exercise of control based on knowledge (Landau 1973). This organization model, based on the principle of functional rationality⁵, pretends to be superior in stability

⁵Here I follow the description of functional rationality that Mannheim made: "Whether a series of actions is functionally rational or not is determined by two criteria: (a) Functional

and reliability and it is supposed to enable a particularly high degree of calculability (Ritzer 1992). The main bureaucratic characteristics that I discern relate to hierarchy, formalization, and the application of rules. The first general hypothesis is that a more bureaucratic organization will be less accident-prone. About some more specific aspects, however, can also be formulated alternative hypotheses. Two potential problems are little flexibility and (lacking) knowledge.

The first problem is created by the division of labor, because of which role specific knowledge will grow at a faster rate than generally relevant and accessible knowledge (Berger and Luckmann 1966:95). Because of increasing formal rationality, a bureaucracy can lead to a wealth of rules and (unnecessarily) specification of tasks. By working too long in a very formalised organization, people develop 'trained incapacity' (Veblen), 'professional psychosis' (Dewey) or 'professional deformation' (Warnotte). The professional experience leads to too much conformism and ritualism (Merton 1968:253, in: Lammers 1989:71). As a result people value too highly the rules within an organization (these rules become an end-in-itself) and lose sight of the real goals, which is called goal displacement. This phenomenon leads to rigidities and an inability to adjust. Goal displacement results in a subconscious urge to ritualistic behaviour, to prevent oneself from being held responsible for mistakes: a so-called 'signature culture'. In such a situation people are preoccupied by their position and experience by which they generate their own goals and transform means into goals.

Related to goal displacement, control creates subjective certainty. The combination of subjective certainty and objective uncertainty is a recipe for 'Type 2' errors (Landau and Stout 1979); i.e. the attempt to control a problem that should be managed. By statistical analogy, this is called a Type 2 error because it is comparable to accepting as true a hypothesis which is false (also: Adams 1995:58). Phenomena as rigidity, loss of flexibility, goal displacement and ritualism can lead to rule-based and knowledge-based errors (Bax 1995:170). Because of rigidity of perception at the

organization with reference to a definite goal; and (b) a consequent calculability when viewed from the standpoint of an observer or a third person seeking to adjust himself to it ... in the definition of functional rationality, emphasis is laid on the co-ordination of action with reference to a definite goal .." (1940:53-54).

individual level, the flexibility of the organization as a whole will be limited. In system terms we can speak about an 'autopoiesis-problem': a system cannot adapt itself to the environment. Flexibility of the organization and different parts is particularly important in a situation of clearly formulated priorities because especially in such a situation is the threat of routine. So the second general hypothesis (seemingly contradictory to the first one) is that inflexible organizations will be accident-prone.

The second problem of lacking knowledge is created by changing circumstances. Control is based on a stable situation. Most accidents seem to happen in complex, diffuse environments under conditions of change (Hale and Hale 1972:64: 'disturbances due to unforeseen circumstances in the task field', Hahn 1980:6: 'hazardous environment, cf. Hirschhorn 1988:82-3). In an unstable situation a gap can develop between plan and reality. Within changing situations plans and standards are not adequate anymore, and controls become deficient (cf. Bird and Germain 1987:28). In such environments adapting formal procedures, perceptions or behaviour is difficult for people. Not just because of ritualism, but because in an uncertain situation the knowledge and information on which P&Is (Procedures and Instructions, or SOPs: Standard Operational Procedures) are based becomes impertinent and inapplicable. For this problem the distinction between control and management is relevant. Before I discuss management I will first discern hierarchy as a separate element of bureaucracy.

3 Hierarchy and responsibility

The more activities are interdependent the more deficient performance of either will affect the performance of the other, and consequently it will be difficult to allocate responsibility for a bad performance. It is needed to reach a certain degree of accountability in problem solving. A common assumption is that authority and responsibility are almost synonyms, or different sides of the same picture. A logical conclusion would be that authority and responsibility for two interdependent activities

should be concentrated in the same person (Thompson 1967: “.. if one wants to divide responsibility, one ought to decouple the activities”, also Stinchcombe and Heimer 1985:69-70).

The result of this assumption is that bureaucratic organizations are often considered to be inflexible hierarchies that do not enable employees to respond to unpredictable situations. Hirschhorn (1993) pictures how procedures and the operating philosophy of ‘verbatim compliance’ pose great difficulties. Verbatim compliance is the idea that workers and supervisors have to comply with the ‘letter of the law’ and implement procedures without deviating from them in any detail. The P&Is cover thousands of work steps and the articulated procedures are incomplete, contradictory, or inaccurate. Because a procedure writer cannot anticipate all situations and conditions, he is likely to commit errors of omission.

At the top of the hierarchy general plans are formulated, these are interpreted, rejected, improved and executed at different levels of the hierarchy. The suggestion of Hirschhorn is that people experience a well-functioning hierarchy as the precondition for (team⁶) work; it prevents employees of being consumed by the politics of their organization. In a hierarchy, the manager represents the interests and goals of the entire organization and deals with the potential conflicts between divisions or departments. So because of his place in hierarchy, the manager ‘integrates’ the organization and avoids conflicts over priorities. Also La Porte and Consolini (1991:36) state that a unity of command is needed to avoid conflicts of expectations arising from the same person being subjected to several sets of authority or organizational modes. And Hirschhorn fills in: “[w]e need to construct hierarchies in which authority is widely delegated, while the chain of command is preserved and secured” (1993:138).

⁶Self-managing teams may be one way to solve the tension between different decision strategies. Teams have a good track record of achieving a positive impact on productivity, job satisfaction and quality of working life. More recently, an increasing number of onshore and offshore process industries (e.g. petrochemicals) have also implemented self-managing teams. Teams would reduce coordination needs. However, there are examples of team implementation, with adverse effects on safety performance. The influence of teams on safety is still unclear according to the Keil Centre (Edinburgh-based firm of Chartered Psychologists: research on self-management and safety, thanks to Annick v.d. Beukel).

Hirschhorn argues that we need to distinguish between hierarchy and bureaucracy: “Working in hierarchies, people can respond flexibly to their task demands. .. Diffusing responsibility and reducing the leader’s apparent accountability, the bureaucracy burdens employees while making it difficult for them to work. Bureaucracies, in effect, deform the hierarchical structure” (1993:138). This hypothesis can be seen as the reversed thesis of Blau (1973:183-206) that a stiff hierarchy causes dysfunctional bureaucratic phenomena. Here it is important to realize that Hirschhorn mainly discusses responsibility, not authority.

Hirschhorn describes several cases (e.g. Three Mile Island) that demonstrate the difficulty of anticipating failures (1988:74-86). Maybe better than anticipation is to improve safety (avoid accidents) as a dynamic product of ‘trial and error’. Errors are informational, compliance or obedience is not (e.g. Van Dyck 2000). For this we would need, instead of a bureaucracy, a more trial-and-error-type of organization (Burns and Stalker, and Mintzberg: organic), to manage unexpected events. Such a decentralized trial-and-error-type recognizes the open aspects of organizations and their political processes. Here we find, low formalization and the necessity to experiment: organizational learning through trial and error. Then a wide diffusion of authority and resources is needed to reach a certain degree of accountability in problem solving and organizational learning. This is the situation that Perrow describes by error reduction below the system-wide level. However, within the ‘high risk industries’ under study, the reliability demands are so intense (and failures so potentially unforgiving) that only a very limited trial-and-error learning about causal relationships is permitted (also: Schulman 1993:34-5).

The higher the demands for operational reliability are, the greater the inherent tension between the two decision strategies; between the comprehensive, systemic, anticipatory bureaucracy and the approximation rooted trial-and-error structure (La Porte and Consolini 1991:28). Mistake-reduction seems to demand apparently contradictory production-enhancing and error-reduction activities. According to Perrow (1999) these different administrative requirements of centralization and decentralization are just part of complex and tightly coupled processes and impossible

to fulfill; a catch 22. Weick (1987) and the Berkeley group (e.g. Eisenhardt 1993) identify the importance of maintaining a tension between centralization and decentralization in 'high reliability organizations', and between two authority modes: hierarchical and collegial. While leaders are ultimately accountable for the organization's performance, a leader delegates substantial authority to his or her subordinates (Hirschhorn 1993:147-9).

It seems as if diffuse, changing situations require a flexible interplay between centralization and decentralization. Responsibility refers to 'who gets the blame', and should always be centralized. An authority structure, on the other side, can be more and less centralized, and the central position can be fulfilled in different ways. Following Hirschhorn, I hypothesize that, especially in hazardous situations, organization members need to feel there is unity of responsibility and a single role through which conflicts, divisions, and tensions within the organization can ultimately be integrated. On the other side, as Perrow (1999) points out, in complex organizations there is sometimes a need to delegate authority. Again: authority delegation is not responsibility delegation; superiors should remain responsible for the proper exercise of authority by their subordinates. Now I would like to explore the concept of authority a little further.

4 Control and management

The distinction between bureaucracy and hierarchy made in the last section, points to the fact that the ideal-typical bureaucracy 'lacks' a clear management aspect. In practice, this is a serious problem because, as stated in the same section, people at higher levels of the hierarchy (the only aspect of bureaucracy which seems to refer to management) should manage most (unexpected) risks. When organizational leaders cannot or will not manage the inherent risks of the enterprise, they paradoxically undermine the hierarchy and create a dysfunctional bureaucracy in its place. But what is 'to manage'? And is management the key to a synthesis between the different requirements of complex and tightly coupled organizations?

Bureaucracy is probably the best known example of an authority structure. It is an authority structure which mainly exists out of control aspects, and by some it is even considered to be a control structure (e.g. Bax 1999). The function of controlling is the assessment of disturbances and correction of performance to make sure that organizational objectives and the plans devised to attain them are being accomplished, usually in a situation in which the activities are repeated. Within a 'closed' organization with clear priorities it is possible to use straightforward, well-programmed P&Is. In other words, there is only routine decision making (Simon 1997) according to a fully rationalized plan.

In their prize winning article 'To Manage Is Not To Control: Or the Folly of Type 2 Errors' Landau and Stout (1979, also Stout 1980) explain that the ability to control a situation means that it is not problematical. There exists a procedure which must be followed exactly because it is an adequate mode of insuring the goal. Situations change however, which means that procedures are no longer adequate. Solutions are different: Selznick states that they require 'critical' decisions, Simon refers to 'non-programmed decision-making', Thompson to 'judgemental' decisions, and Braybrooke and Lindblom argue for reversible 'incremental' choices. In all cases, the terms take their meaning from situations marked by a wide range of potential surprise (Landau and Stout 1979). Solutions to problems cannot be commanded, they must be discovered: found by analysis, experiment and criticism.

Control requires a high degree of (tayloristic) division and rules, while management calls for overview and flexibility (e.g. Romzek and Dubnick 1987). Control can be seen as functionalisation, i.e. the creation of (sub)tasks as part of the production process by task specification. This is the degree in which the specific functions are specified internally (formalized) by P&Is, specifying the execution of, and supervision on, the different (more or less empowered) tasks (freely rendered from de Sitter 1987). But it also involves the attitude of employees towards these rules. Planning and controlling are closely related. Management on the other side is a coordinating activity: 'organizing'. It can also be seen as a planning process, but it is less 'automatic' and no prescribed way of carrying out an activity or set of activities exists.

Control refers to a (high) division of labor within a group of roles and a (detailed) job design, management is the coordination between and within these roles (the goals and tasks so divided). Management is unsystematic, a situation is encountered that the rules do not deal with. Control relies on formal rules and knowledge about these rules, management relies on attempts at thinking through the consequences of the planned actions. Simplified: control demands knowledge, management involves thinking. An additional characteristic, filled in by Bax (1995:169), is that “disturbance detection and risk management have to be located on the spot”, while control can be executed from a distance in time or place. Control depends on knowledge, knowledge that often does not exist in uncertain environments. Managing is necessary therefore, i.e. assume more flexible responses. (Anthony Oettinger in Landau and Stout: “management is the art of making decisions with insufficient information”). Landau and Stout (1979:149) conclude that “[t]here is an inverse relationship between the ability to control and the necessity to manage”.

On the other side, if the situation is not stable, control requires management: the more divided the different parts of the control structure are, the more they require to be coordinated by management. So, under assumption of clearly specified goals and a stable environment, I expect a bureaucratic control structure to emerge. But, within a diffuse and changing environment, I expect authority to be executed by management. In other words, to improve flexibility, it is needed to complement the substitute relation assumed by Landau and Stout, with a supplementary relation. So, management is both a substitute (or from a bureaucratic point of view: surrogate) for control; one needs management when there is uncertainty to be resolved (e.g. in a situation without detailed job codification), and it is supplementary to the division of labor (the further the division of labor proceeds the more coordination they need).

It is unclear whether the organization should anticipate on every risk, or whether it should trust on the possibility to react creatively to disturbances close to their sources. Because of their potential results towards the environment, it is unlikely that high risk industries (like the organizations under study) can permit themselves such a system of trial-and-error, and whether this is suitable within complex and tightly coupled

processes in general. I expect that the organizations under study know a high degree of (bureaucratic) control, and (because of that, in uncertain situations) require a lot of management.

Hirschhorn (1993) uses the concept 'leadership' to refer to the coordination, or combination of (sub)tasks. During the field work (which will be described in the next section) I often heard the term 'coaching leadership' as a desired quality of supervisors. It involves explaining subordinates why decisions were made, finishing conflicts within a department/team/shift, motivating subordinates, etc. The respondents described it as a way of management which reflects both 'structure': the extent to which a supervisor facilitates group interaction toward goal attainment (communicating information, scheduling, trying out new ideas, and so on); and 'consideration': the extent to which a supervisor is likely to have job relationships characterized by mutual trust, respect for subordinates' ideas, and consideration of their feelings. Now the distinction between structure and consideration will not be followed any further, because here I only want to explore the general influence of (coaching) leadership⁷.

It seems as if safe organizations are hierarchies with a flexible delegation of authority while the responsibility is centralized. So even while responsibility should always be centralized, and the amount of control will always be stable, management is more flexible. Management makes it possible to have a more flexible authority structure which can adapt itself by changing its degree of centralization. To test the general hypotheses I will first relate accident-proneness to a general bureaucracy scale and a flexibility scale. To explore more specific hypotheses about control I will relate planning, task specification and verbatim compliance to accident-proneness. To study the influence of responsibility and management aspects I will relate accident-proneness to responsibility and the hierarchical aspects of centralization and span of control, extended with coaching leadership.

⁷For the distinction between structure and consideration see Miller 1991:441

5 Field study

For a useful contribution, I need to study complex and tightly coupled organizations that can be characterized as 'high risk', and would require contradictory administrative requirements. Because of these requirements I chose the chemical industry as object of study.

The research was executed within eight organizations. A field study during a shut-down, within one of the eight organizations under study, consisted out of participating research and interviews. The main goal was to do observations to obtain an inward view of the production process, the course of a shut-down, the main tasks of the different functions and departments, the coordination process during toolbox and other meetings, etc. Beside this, within six of the eight organizations, more than twenty interviews were conducted with plant managers, safety officers and other key-persons.

Because of statistical reliability finally a questionnaire approach was chosen. Based on the interviews, and scales derived from literature (e.g. Miller 1991) several survey items were applied to the situation within the chemical industry. In May 1999 this survey was sent to all employees within the production, maintenance and shipping sequences within organizations A - H, and their staff. The respondents were operators, (different kind of) engineers, shippers, support staff, supervisors, etc. 436 employees cooperated within the research (equals 56% response). The response can be qualified as a relatively high one (at least for Dutch standards).

The eight organizations can be described by some simple indicators (table 1). At first sight the most startling numbers are the ratio between executive and non-supervisory staff within organization D, and the one between production and maintenance within organization A. The last ratio could be explained by the fact that the maintenance department of organization A was actually working within three different organizations (A, C and G).

Table 1: Characteristics of the survey respondents

Organization	A	B	C	D	E	F	G	H	Total
Response %	56	60	72	39	65	52	65	76	56
Response #	44	36	29	81	52	83	36	75	436
Production*	21	26	21	45	41	55	29	54	292
Maintenance	20	8	5	30	6	23	5	15	112
Other**	3	2	3	6	5	5	2	6	32
Supervisory staff	15	13	12	41	15	30	13	27	166
Non-supervisory staff	29	23	17	40	37	53	23	48	270

note: *: includes shipping department. **: includes technology department and staff

(In case of some scale-analysis $N > 436$ because of inclusion of organization I).

Organizations A - H are organizations within Dutch chemical industry and they operate around different processes related to the exploration of gas, and the production of base - and functional chemicals. They are, as a joint venture or as a full daughter, part of multinational companies. To preserve confidentiality, these organizations will not be described in more detail.

6 Measurement

For measurement ten different scales were used. Accident-proneness consists out of two aspects. Four items measured (near-) accidents and the employees' general opinion about the safety within their organization, e.g.: 'How many accidents did you witness within the last three years?', 'Were you involved yourself?', and 'Employees often have to do their work under dangerous circumstances.' (total score: 0 - 17). Another six items measured mistakes and risk-taking behaviour (by colleagues), e.g.: 'many employees don't have enough skills to fulfill their task in a safe way', and 'many employees push their luck too much' (total score: 0 - 16). The accident-proneness scale is an equal weighted combination of the two subscales (Crombach's Alpha = .7513; N 434, total score: 0 - 33). (For development and validation of this measurement device see Van As 2000).

Bureaucracy is a general construct with many different dimensions. For a general impression I partly adapted a 'general bureaucracy scale' of thirteen items from Van Aken (1996). A general question: 'would you like to typify the way of working within your organization?', was followed by items like 'precise - sloppy', 'formalized procedures - ad hoc measures', and 'formal - informal'. Two of these item-pairs however showed not to be really 'part' of this bureaucracy scale. These were the items 'conservative - innovative' and 'sluggish - promptly'; which seem to refer to (in-)flexibility. After removing these items from the scale, the alpha score improved from .7171 to .8293 (three point scales; N 433, total score: 0 - 22). This is an indication that flexibility and bureaucracy do not seem to be contradictory characteristics, or at least that inflexibility is not a 'general bureaucratic' characteristic.

To measure inflexibility only four items are used based on the 'sluggish - promptly' item (removed) from the general bureaucracy scale, completed with three items about the disturbing influence of unexpected events (Likert scales, low Alpha = .5775; N 450, total score: 0 - 14). E.g. 'Our organization adapts very easy to such a situation' and 'Such a situation creates a lot of tension'.

The control dimension of authority structure can be measured by many different aspects. During the interviews the same aspects were mentioned by most respondents. Because of their importance within the chemical industry, and their potential influence on accident-proneness I measured three related concepts: planning, task specification, and verbatim compliance. To measure planning ten items are used, which were (partly) adapted from different scales to measure the use of planning (and project) instruments, as developed by Van Aken (1996:182) (Likert scales, Alpha = .7028; N 167, total score: 0 - 40). The N is limited because these questions were only to be answered by supervisors. Examples are: 'I use planning instruments (swot, scenario's, critical point/hazops)' and 'In case of planning many important things are usually forgotten'.

Task specification (or: job codification) is the regulative or task-related network pertaining to policies, procedures and rules. It can be seen as the result of planning, and it relates to P&Is. The items are partly based on the formalization scale

of Hage and Aiken⁸ (in: Miller 1991:407-9) and the project survey of Van Aken 1996. The measure reflects a degree of job codification by nine items. These are about whether decisions have to be made by employees themselves, or by procedures they have to follow (Likert scales, Alpha = .6423; N 425, total score: 0 - 18). E.g. 'In our organization everyone has a very specific task' and 'Do you have to do things for which no procedures exist?'

The planning and task specification measures can be very unrealistic because employees are not simple executants. There is an indispensable distinction between prescribed task and real task. Therefore I distinguish a third dimension of control that involves (contra) procedural attitude and behaviour, and monitoring job occupants to ensure conformity to the rules: verbatim compliance. This scale is partly based on the Aiken-Hage measure and items from the Dutch survey 'Nationaal Onderzoek - DBI'⁹. The 10 items are about the difference between the formal rules and the actual use of these rules, and reflect the degree of rule leniency (Likert scales, Alpha = .7473; N 428, total score: 0 - 40). E.g. 'Procedures are mainly about things that are not important' and 'Procedures are only guidelines where you can deviate from'.

I distinguished authority from responsibility. To measure responsibility only one item was used: "The supervisor finally gets the blame if an accident happens" (Likert scale, N 431, total score: 1-5). The hierarchical position of the supervisor is not taken into consideration.

As stated before, the only aspect of bureaucracy that refers to management is hierarchy. Two aspects of hierarchy that seem of special importance in case of management are the span of control and the degree of centralization. I extended these facets with a third aspect: coaching leadership. To measure span of control one question was asked, and only to supervisory staff: 'How many subordinates do you supervise?' The level or stratum in the organization is not taken into consideration,

⁸Hage and Aiken distinguish two dimensions of formalization: "job codification, or the degree of work standardization, and rule leniency, or the measure of the latitude of behavior that is tolerated from standards". Here the second dimension is measured separately by another scale: verbatim compliance.

⁹Nationaal Onderzoek - Documentatie van Bedrijfsprocessen en Innovatievermogen - Erasmus University Rotterdam 1995.

neither is the hierarchical position of the subordinates. The answers were corrected for outliers by categorizing the amount of subordinates to four classes: one till three subordinates, four till six, etc (N 166, total score: 1-4).

To measure centralization six items were used, which were adapted from the centralization scale as developed by Hage and Aiken (in: Miller 1991:409-12). Centralization is the degree to which authority is concentrated in an organization. The maximum degree of centralization would exist if all authority is exercised by a single individual; the minimum degree of centralization would exist if all authority is exercised equally by all members of the organization. The items measure the degree to which individuals participate in decisions about the tasks associated with their position, the allocation of resources and the determination of organizational policies. So, it is a combination of the degree in which authority is exercised by a single individual and the degree in which subordinates participate in decisions involving their work and work environment (Likert scales, low Alpha = .5606; N 453, total score: 0 - 24). E.g. 'The procedures are formulated in consultation' and 'For almost everything I do, I have to ask my supervisor whether he agrees with it'.

(Coaching) leadership is probably the most esoteric concept of all. As stated before I am only interested in the general concept of coaching leadership. It refers to how much confidence and trust is shown in subordinates, how often subordinates ideas are sought and used constructively, etc. (Wehrich and Koontz 1993:498). To measure coaching leadership ten items are used, partly derived from the 'Supervisory Behaviour Description' (Miller 1991:445-6), Leader behaviour description questionnaire of Stogdill (in: House and Rizzo 1972) and the 'community general hospital research' (Georgopoulos and Mann 1962:644-7) (Likert scales, Alpha = .8862; N 448, total score: 0 - 40). A general question ('would you like to typify whether these items fit your supervisor?') was followed by items like 'He makes very clear what he expects from people' and 'He sometimes changes the duties of people without consultation'.

7 Analysis

Based on the interviews, I did not expect significant differences between the organizations on bureaucracy and flexibility. (Except of course a worse score for more accident-prone organizations; closer to H). All respondents were well aware that their organization knew many bureaucratic characteristics. The amount of P&Is is impressive, there is a lot of planning, etc. Also according to 'objective' measures the formal rules should be more or less the same: e.g. organization A and G both have an ISO 14001 certificate. In general the bureaucratic characteristics were considered to be undesirable and inevitable by most respondents.

Table 2: Bureaucracy and inflexibility by organization (means)

Organization	A	B	C	D	E	F	G	H	Total
Proneness	9.9	10.7	11.0	11.1	12.3	12.3	12.9	13.4	11.6
Bureaucracy	16.3	15.7	16.4	14.2	14.8	17.1	16.4	15.2	15.6
Inflexibility	6.1	5.3	6.1	7.0	6.9	6.2	6.5	6.7	6.5

One-Way ANOVA: Accident-proneness: $F = 3.050$; $df = 7$; $Sig. = .004$

Bureaucracy: $F = 3.679$; $df = 7$; $Sig. = .001$

Inflexibility: $F = 3.385$; $df = 7$; $Sig. = .002$

The aspects of authority structure and accident-proneness will be analyzed by One-Way ANOVA. For this several tests can be used. The F test is an extension of the two-sample t test and produces an analysis of variance for a quantitative dependent variable (e.g. accident-proneness) by an independent variable (organization). It provides me with a value that represents the average sum of squares between the different groups divided by the average sum of squares within the groups. Many different tests can be used for post hoc pairwise multiple comparison tests. In this research I used the Scheffe test and Sidak's t test. The Scheffe test is the most conservative test, which means that a larger difference between means is required for

significance. Sidak's t test provides tighter bounds than the more commonly used Tukey's HSD or Bonferroni test.

On accident-proneness the Scheffe test does not show any significant differences. But Sidak's t test shows significant differences between organizations A and H, B and H, and D and H (table 2). On bureaucracy both the Scheffe test and Sidak's t test only show a significant difference between the organizations D and F. This difference is contradictory to my hypothesis. However, we could not detect a significant difference on accident-proneness between D and F (only the LSD test shows a significant difference between these two organizations on accident-proneness), so the difference on bureaucracy does not seem very meaningful.

On inflexibility the Scheffe test only shows a significant difference between organizations B and D. While Sidak's t test shows significant differences between B and D and between B and E (which are not significantly different on accident-proneness). So the general hypotheses that a more bureaucratic organization is less accident-prone, and an inflexible organization is accident-prone, are falsified. The last, and probably most surprising conclusion I can draw from table 1 and 2 is that an organization with an exceptional ratio between executive and non-supervisory staff (organization D) is the least bureaucratic, and at the same time a (significantly) inflexible organization. A possible explanation for this last characteristic are the long lines of coordination within the hierarchy, which knows (too) many layers.

Risk control:

According to most (interview) respondents their organization and its technical process are so complex and dangerous that a lot of planning, and many formal rules cannot be avoided. About verbatim compliance the opinions are different, not just between organizations but also within organizations. Some respondents were convinced that most accidents happened because P&Is were not followed. Other respondents argued that they "didn't want trained monkeys on the plant". I did not expect many significant differences between the organizations, and even not a particular trend because about every control aspect an alternative hypothesis can be formulated.

Table 3: Control aspects by organization (means)

Organization	A	B	C	D	E	F	G	H	Total
Planning	26.0	27.3	22.9	25.5	24.6	25.7	23.5	24.2	25.1
Task specification	18.7	20.1	19.8	20.9	20.4	21.3	21.9	21.4	20.7
Verbatim compliance	28.0	29.9	27.4	26.7	27.1	28.6	28.5	27.4	27.8

One-Way ANOVA: Planning: $F = 1.175$; $df = 7$; $Sig. = .320$

Task specification: $F = 2.602$; $df = 7$; $Sig. = .012$

Verbatim compliance: $F = 2.052$; $df = 7$; $Sig. = .048$

Analyzed at the organizational level (table 3) the influence of planning is unclear, especially organization C scores too low. As can be derived from the F test, which is not significant, the influence of planning could not be observed. Another observation is that a lot of planning does not (automatically) mean more task specification. On task specification Sidak's t test shows significant differences between organizations A and F, A and G, and A and H. So, the influence of task specification can be recognized. On verbatim compliance Sidak's t test shows only one significant difference, between organizations B and D. Because we did not detect a significant difference between these organizations on accident-proneness, this difference is not very meaningful.

The analysis shows significant differences on task specification and verbatim compliance. Based on this analysis I conclude that tasks specification has an unfavorable (positive) influence on accident-proneness. The score of organizations F, G and H seem to indicate that task specification should not exceed a certain value (around 21). The score of organization A indicates that especially a very low score (below 19) can be a very favorable contribution to safety. Contradictory to the prediction of Hirschhorn verbatim compliance does not seem to have an unfavorable (positive) influence on accident-proneness. There is even some (very modest) proof that verbatim compliance can be a 'safe attitude'. So, a 'safe' organization does not know many P&Is, or task specification, but (maybe) these rules should be carried out conscientiously. The influence of planning is unclear.

Risk management and responsibility:

During an interview, the plant manager of organization C told me that his organization knows a high degree of centralization. This is “an advantage in times of crisis, the only disadvantage is the limited bottom up input”. However, according to respondents within other organizations (including C), organization D, F and H were “even more centralized by tradition” (because of their focus on one product, or because of state ownership in the past). The enthusiasm in the field, made me expect a very strong correlation between coaching leadership and accident-proneness (so: a higher score for less accident-prone organizations; closer to A).

Table 4: Management aspects by organization (means)

Organization	A	B	C	D	E	F	G	H	Total
Centralization	9.5	9.7	10.3	10.0	9.6	10.7	10.0	10.7	10.2
Span of control	2.1	1.9	1.5	2.3	3.5	2.6	2.1	2.8	2.4
Coaching leadership	26.3	26.6	25.0	25.5	24.9	24.6	25.1	22.3	24.8
Responsibility	2.6	2.5	2.6	2.9	2.4	2.2	2.5	2.3	2.5

One-Way ANOVA: Centralization: $F = 2.366$; $df = 7$; $Sig. = .022$
Span of control: $F = 5.947$; $df = 7$; $Sig. = .000$
Coaching leadership: $F = 2.746$; $df = 7$; $Sig. = .009$
Responsibility: $F = 3.336$; $df = 7$; $Sig. = .002$

No significant differences can be detected on centralization of authority (table 4). One possible explanation for this is the difference between degree of centralization and flexibility of centralization. As the plant manager of organization A said about being flexible: “normally I’m 90% of my time at the office, and only 10% on the plant itself. But, during shut-downs and disturbances it’s the other way around”. And: “There are people that I listen at, and there are people that I talk to ... I tell them what should happen, they tell me how.” Especially the last statement points at the

possibility to measure flexibility by looking at the variance, instead of the means. However, this also does not show very meaningful results: Organizations A, F and H know a lot of variance in centralization (above 6, not in table), while organizations C and G know a little variance (below four). So, no trend can be observed, only organization F and H know a high degree of centralization and a lot of variance. This seems to point at the impossibility of a 'real' (general) high degree of centralization.

Significant differences can be detected on span of control. The Scheffe test shows differences between organizations B and E, and C and E. Sidak's t test also shows significant differences between A and E, B and E, C and E, C and H, D and E, and (only) one difference that is contradictory to my expectations: between E and G. On coaching leadership Sidak's t test shows significant differences between A and H, and between B and H. On responsibility the Scheffe test shows significant differences between organizations D and F, and between D and H. Sidak's t test shows significant differences between D and E, D and F, and between D and H. These differences do not falsify the hypothesis of Hirschhorn.

I conclude that span of control has an unfavorable (positive) influence on accident-proneness. A more surprising observation is the relatively high average span of control in organization D, despite its high ratio of supervisory staff. It also looks as if a small span of control is not a prerequisite for coaching leadership in organizations. Based on the empirical analysis, I conclude that coaching leadership can be a favorable (negative) contribution to accident-proneness. The influence of centralization is unclear. Not just analytically but also empirically, authority can be distinguished from responsibility. Responsibility can also be a source of accident-proneness, and should always be centralized. Some exceptions show that, just like the control aspects, none of these factors is all decisive.

8 Conclusions

In this paper I tried to explain mistakes and accidents from out of organizational characteristics. The overall conclusion can be summarized briefly. The characteristics I studied were derived from the ideal typical bureaucracy. I discerned hierarchy as a separate element, and made a distinction between control and management. It is still unclear whether an accident-prone organization is bureaucratic, or knows a lot of planning, but within a safe organization the degree of task specification should be limited and not exceed a certain value. And there is some modest proof that these P&Is should be carried out conscientiously (verbatim compliance). It is not very clear whether a safe organization is flexible, or knows a high degree of (de)centralization. But the span of control should be limited and coaching leadership has a favorable (negative) influence on accident-proneness. The original explanation for this is that these management characteristics make the authority structure more flexible. Finally, responsibility should always be centralized.

References

- Adams, J. 1995: *Risk* (London, ISBN 1-85728-068-7)
- Aken, T.G.C. van 1996: *De weg naar projectsucces: eerder via werkstijl dan via instrumenten* (Utrecht, ISBN 90-352-1726-8)
- Bax, E.H. 1995: *Organization and the Management of Risk in the Chemical Process Industry*, in: *Journal of contingencies and crisis management* (September, Vol.3, #3, p.165-80)
- Bax, E.H. 1999: *The Paradox of Bureaucratic Risk Control*, paper for the 2nd International Conference on Risk Management (Liège, Belgium, 5-7 May)
- Bea, R.G. and W.H. Moore 1993: *Operational Reliability and Marine Systems*, in: K.H. Roberts (ed.) *New Challenges to Understanding Organizations* (New York, ISBN 0-02-402052-4)
- Berger, P.L. and T. Luckmann 1966: *The Social Construction of Reality – A Treatise in the Sociology of Knowledge* (New York, ISBN 0-385-05898-5)
- Bird, F.E.Jr. and G.L. Germain 1987: *Practical Loss Control Leadership* (Loganville, ISBN 0-88061-054-9)
- Blau, P.M. 1973: *The Dynamics of Bureaucracy: a Study of Interpersonal Relations in Two Government Agencies* (Chicago, ISBN 0-226-05726-7)
- Dyck, C. van 2000: *Putting Errors to Good Use: Error Management Culture in Organizations* (UvA, ISBN 90-76269-15-7)
- Eisenhardt, K.M. 1993: *High Reliability Organizations Meet High Velocity Environments: Common Dilemmas in Nuclear Power Plants*, in: K.H. Roberts (ed.) *New Challenges to Understanding Organizations* (New York, ISBN 0-02-402052-4)
- Georgopoulos, B.S. and F.C. Mann 1962: *The Community General Hospital* (New York, ISBN 0-8240-8205-2)
- Hahn, C.P. 1980: *Overview of Models of the Accident Phenomenon*, in: *Readings in Industrial Accident Prevention*, Petersen and Goodale - ed. (New York, ISBN 0-07-049591-2)
- Hale, A.R. and M. Hale 1972: *A Review of the Industrial Accident Research Literature* (London, ISBN 0-11-360895-0)
- Heinrich, H.W. 1959: *Industrial Accident Prevention – a Scientific Approach* (4th.ed. New York)
- Hirschhorn, L. 1988: *Beyond Mechanization: Work and Technology in a Postindustrial Age* (London, ISBN 0-262-58081-0)
- Hirschhorn, L. 1993: *Hierarchy Versus Bureaucracy: The Case of a Nuclear Reactor*, in: K.H. Roberts (ed.) *New Challenges to understanding organizations* (New York, ISBN 0-02-402052-4)
- House, R.J. and J.R. Rizzo 1972: *Toward the Measurement of Organizational Practices*, in: *Journal of Applied Psychology* (Vol.56, #5, p.388-396)
- Lammers, C.J. 1989: *Organisaties vergelijkenderwijs* (Heerhugowaard, ISBN 90 274 6256 9)
- Landau, M. 1973: *On the Concept of a Self-Correcting Organization*, in: *Public Administration Review* (November/December, p.533-42)
- Landau, M. and R. Stout.Jr. 1979: *To Manage Is Not To Control: Or the Folly of Type II Errors*, in: *Public Administrative Review* (March/April, p.148-56)

- LaPorte, T.R. and P.M. Consolini 1991: *Working in Practice But Not in Theory: Theoretical Challenges of "High-Reliability Organizations"*, in: Journal of Public Administration Research and Theory (January, #1, p.19-47)
- Leplat, J. 1987: *Accidents and Incidents Production: Methods of Analysis*, in: Rasmussen, et al (ed.) *New Technology and Human Error* (Chichester, ISBN 0-471-91044-9)
- Mannheim, K. 1940: *Man and Society in an Age of Reconstruction: Studies in Modern Social Structure* (London, ISBN 0-7100-1788-X)
- Merton, R.K. 1968: *Social Theory and Social Structure* (enl.ed. New York, ISBN 0-02-921130-1)
- Miller, D.C. 1991: *Handbook of Research Design and Social Measurement* (5th edition Newbury Park, ISBN 0-8039-4219-2)
- Osborn, R.N. and D.H. Jackson 1988: *Leaders, Riverboat Gamblers, or Purposeful Unintended Consequences in the Management of Complex, Dangerous Technologies*, in: Academy of Management Journal (Vol.31, #4, p.924-47)
- Perrow, C. 1999: *Normal Accidents: Living With High-Risk Technologies* (New York, ISBN 0-691-00412-9)
- Reason, J.T. 1990: *Human Error* (Cambridge, ISBN 0-521-30669-8)
- Ritzer, G. 1992: *Sociological Theory* (3th edition, New York, ISBN 0-07-052971-X)
- Romzek, B.S. and M.J. Dubnick 1987: *Accountability in the Public Sector: Lessons from the Challenger Tragedy*, in: Public Administrative Review (May/June, p.227-38)
- Sagan, S.D. 1995: *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons* (Princeton, ISBN 0-691-02101-5)
- Schulman, P.R. 1993: *The Analysis of High Reliability Organizations: A Comparative Framework*, in: K.H. Roberts (ed.) *New Challenges to understanding organizations* (New York, ISBN 0-02-402052-4)
- Simon, H.A. 1997: *Administrative Behavior – A Study of Decision-Making Processes in Administrative Organizations* (New York, ISBN 0-684-83582-7)
- Sitter, L.U. de 1987: *Op weg naar nieuwe fabrieken en kantoren: Produktie-organisatie en arbeidsorganisatie op de tweesprong* (Deventer, ISBN 90 267 0730 4)
- Stinchcombe, A.L. and C.A. Heimer 1985: *Organization Theory and Project Management: Administering Uncertainty in Norwegian Offshore Oil* (London, ISBN 82-00-07600-8)
- Stout, R.jr. 1980: *Management or Control? The Organizational Challenge* (London, ISBN 0-253-12082-9)
- Thompson, J.D. 1967: *Organizations in Action: social science bases of administrative theory* (New York, ISBN 0-07-064380-6)
- Van As, S. 2001: *The Measurement of Accident-proneness* (SOM Research Report, in review)
- Weber, M 1968: *Economy and Society: An Outline of Interpretive Sociology* - part 1: conceptual exposition (New York, Lib.of Cong. 68-27095)
- Weick, K.E. 1987: *Organizational Culture as a Source of High Reliability*, in: California Management Review (Winter, Vol.29 #2, p112-27)
- Wehrich, H. and H.D. Koontz 1993: *Management: A Global Perspective* (New York, ISBN 0-07-112892-1)